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ATS More Efficient, Cleaner Power Generation

In addition to boosting efficiency, which means less fuel is used and therefore fewer pollutants are released into the air, other improvements developed through the Advanced Turbine Systems (ATS) Program are so successful that turbine manufacturers have already incorporated them into current models.

The Federal Energy Technology Center (FETC) is addressing the challenge of utility deregulation by developing advanced turbines. In a combined cycle system, these machines will be 10 percent more efficient and will produce less than half of the nitrogen oxides of currently commercial gas turbine systems. Equally important to the utility and the consumer, as long as natural gas prices remain at current levels, these systems will produce electricity at lower cost than any other new generating source.

“DOE-supported ATS technology has already yielded benefits for current combustion turbines,” notes Abbie Layne, FETC’s ATS product manager. Specific turbine designs aside, the program has led manufacturers to upgrade existing equipment through better blade development, coatings, and similar improvements.

A case in point is the transfer of ATS technology to General Electric’s gas turbines and their suppliers. Airfoil casting development, which deals with creating turbine blades, has improved with the use of manufactured, thin walled, complex, single crystal castings for future advanced gas turbines. Single crystals, much stronger than the multi-directional crystal design now used in manufacturing blades, are better able to resist high temperatures, cracking, and other problems associated with turbine use. And the methodology employed by GE and a major casting supplier has improved the way blades are produced and the number of blades that are produced. As a result, future thin-walled airfoil development programs are expected to achieve quality and cost targets at a faster rate. In addition, selected process improvements, like new core support methods, are already part of a

The General Electric Corporation's G gas turbine product line features improved blade design and enhanced thermal barrier coatings.



program to enhance GE's F gas turbine product line. Also planned for near term F-product enhancements are thermal barrier coatings.

Areas being explored in the ATS Program include telemetry technology, which uses radio-like signals to measure a blade's rotations and vibrations. This technology adds new capabilities for obtaining real-time data to characterize gas-turbine operating behavior, and is being considered for three significant new product development programs. Pyrometer technology, measuring a blade's temperature and other factors, is being evaluated as a way of helping evaluate the condition of gas turbines in GE's fleet. This enhanced monitoring capability is expected to add value to maintenance and life-extension activities.

Capturing a Growing Global Market

The object of such improvements is a very sizable market. Right now, gas turbines are a \$3.5 billion industry in the United States. Globally, the market promises to be huge. From 1997 to 2006, Forecast International, a private marketing and consulting firm, expects the gas turbine industry will reach \$251 billion with worldwide power generation accounting for \$86 billion. Industrial and marine uses are expected to represent \$96.5 billion during the same time period.

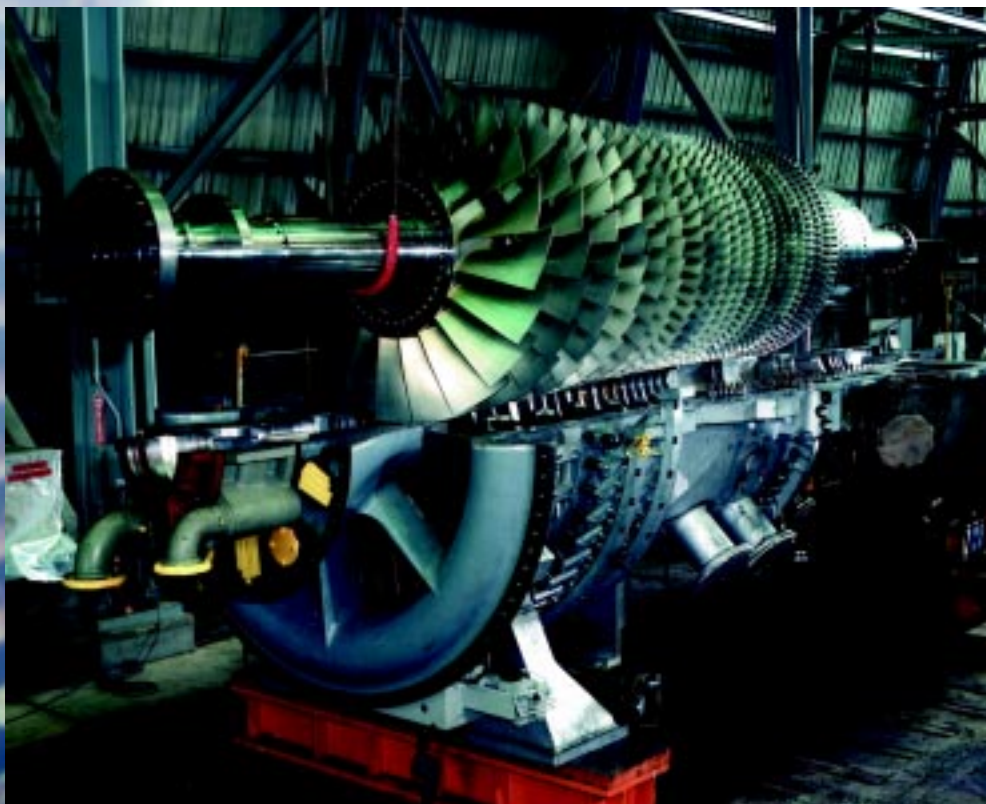
Advanced turbines are poised to dominate the majority of this power market, primarily because the ATS design is being incorporated into today's turbines and existing technologies to boost efficiency. Current ATS strides put overall efficiency at slightly more

than 60 percent for utility-scale systems, a significant jump over the 42-percent efficiencies that the best coal plants now achieve.

Another dimension that enhances ATS's attraction is its fuel flexibility. ATS will have the capability to operate on a coal-derived synthesis gas as well as natural gas, the most commonly used fuel today.

There is no doubt that gas turbines fueled by natural gas or a coal-derived synthesis gas will take on a significant role in providing heat and energy for power generation, cogeneration, and steam turbine combined cycles in the foreseeable future. In fact, the Energy Information Administration estimates that gas turbines will satisfy as much as 81 percent of new electric power demands in the United States alone. A study sponsored by Westinghouse Electric Corporation

Installation of the Westinghouse Electric Corporation compressor rotor into the compressor casing. The compressor is the largest, highest pressure ratio, 60 Hz utility combustion turbine compressor ever built.



projects the total world demand for electricity will exceed 1,690 gigawatts (GW) between the year 2000 and 2014. The utility-scale potential market is quite large, more than 300 GW. It is a demand that will be met by simple- and combined-cycle ATS. The market for small industrial-scale ATS is expected to be about 127 GW.

Slicing Up the Market

Natural gas, the entry-level fuel for ATS generation, is projected to supply 473 GW of this market. Advanced solid-fuel power systems now being developed are expected to incorporate ATS turbines, resulting in a larger market for these machines. Utility ATS penetration into the market for integrated gasification combined-cycle (IGCC), pressurized fluidized-bed combustion (PFBC), and indirect-fired cycle (IFC) systems is expected to begin in 2005, as solid-fuel-based power-system commercialization accelerates. IGCC systems could capture 40 GW of the world's power-generation market by 2006, says Forecast International.

Program participants are also studying the benefits of integrating ATS designs into coal-fired cycles, such as IGCC. The IGCC plants now in operation are funded through the Clean Coal Technology (CCT) Program because they can use a coal-based gas. In addition to data from these CCT projects, laboratory combustion studies being conducted at FETC are evaluating fuel flexibility for industrial-scale systems as well as utility use.

The huge potential market will drive future gas turbine technology to produce energy in a reliable, cleaner, more efficient, and less costly manner than ever before.

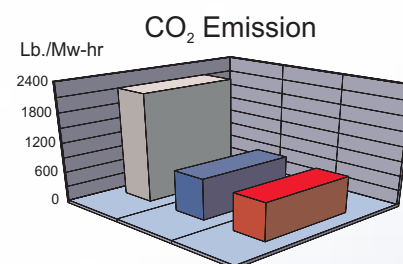
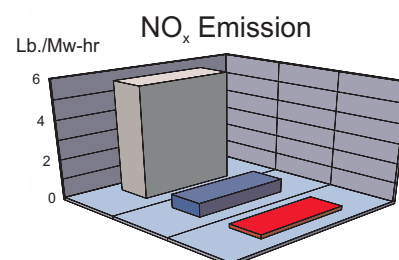
Market Drivers, Global Competition

While these factors are the drivers behind the introduction of ATS technology, the primary emphasis is on emissions. The growing need to lower emissions, especially NO_x and CO_2 , and a demand for high efficiencies to keep natural gas consumption and costs low are the most important reasons behind ATS evolution. New ATS designs evolving through the program, projects Ms. Layne, will reduce NO_x to less than 9 parts per million (ppm).

High efficiencies, of course, also reduce production of CO_2 , which a report from the Intergovernmental Panel on Climate Change suggests is having a discernible influence on global climate. CO_2 has increased by 25 percent over the past century. That is a fact that most experts agree on. What is less certain is where we go from here.

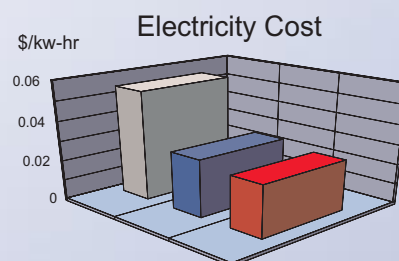
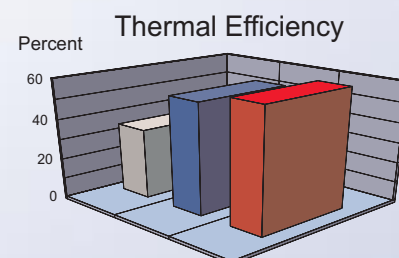
U.S. manufacturers have dominated the worldwide gas turbine market since its inception. But recently, foreign systems have capitalized on breakthroughs and improvements that advance the technology. A major leap is required for American manufacturers to regain their edge in this vital technology that is sure to capture the bulk of the burgeoning electric-generation market.

A New Standard In Environmental Stewardship



- Less NO_x in one year than existing plants produce in under two weeks
- Less CO_2 in one year than existing plants produce in under four months
- No acid rain producing SO_2
- Billions of dollars saved on environmental compliance—better economic competitiveness

60% Efficiency Breakthrough



- \$7.0B in consumer electricity savings by 2015
- Enough gas savings to heat over 17 million homes by 2015
- ATS fuel savings over 300,000 barrels of oil per day by 2015
- Over 70% efficiency improvement vs conventional steam

- Existing coal power plant
- Current combined-cycle gas turbine
- Advanced combined-cycle gas turbine

The DOE ATS Program

These developments emphasize the vital need for the federal government to participate in technology development. DOE recognized this need in 1992 when it initiated the ATS Program. This program combines the resources of the government, major turbine manufacturers, and universities to advance gas turbine technology and to develop systems for the 21st century.

DOE and individual participants fund ATS projects in such a way that the level of cost-sharing from the participants increases as the technology risk decreases. During the final phases of the ATS Program, participants will provide more than half of the financial support needed to sustain the Program.

Two ATS Classes

- The simple-cycle industrial gas turbine is being developed for distributed generation and industrial and cogeneration markets.
- The combined-cycle gas turbine is being developed for use in large, baseload, central station, electric power generation markets.

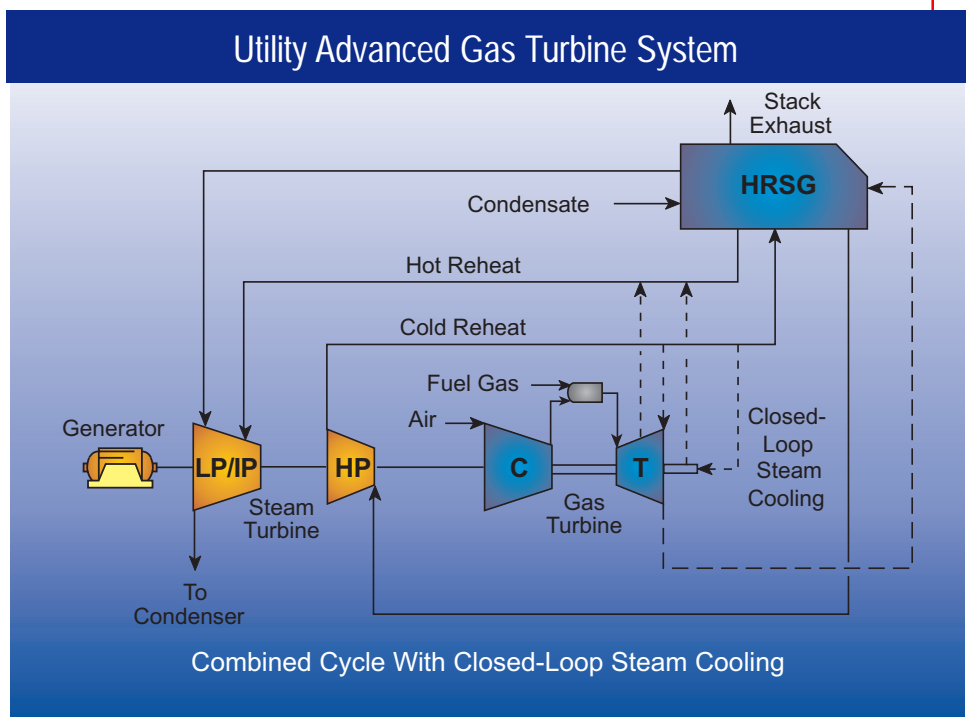
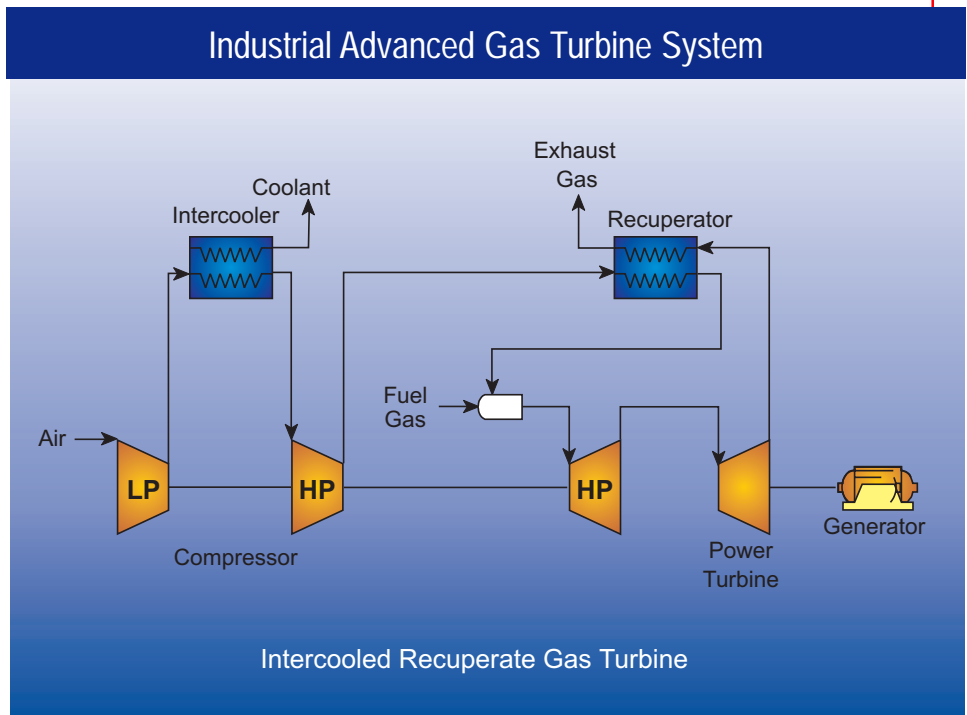
ATS development consists of two major, interrelated thrusts:

1. Major Systems Development

is carried out by turbine manufacturers actively engaged in developing an ATS. Four corporations are working on detailed engine designs and hardware through the technology readiness and validation testing phase within the program.

2. Technology-Base Research

supports the development of major systems, but the primary



concern is evaluating future advancements for gas turbine systems. Academic research and applied research not slated to be used in future ATS demonstrations is pursued in technology-base activities.

The Office of Fossil Energy supports the utility-scale system development, industry/university consortium, materials research for single crystal turbine components, FETC technology-base research and development, and ATS applications for coal-derived fuels.

The Office of Energy Efficiency and Renewable Energy supports the industrial-scale system development, materials research on thermal barrier coatings, ceramic retrofit engine development, and ATS applications for biomass fuels.

Today four major turbine manufacturers are participating in Phase III of the ATS Program, the technology readiness and validation testing stage. Allison Engine Company and Solar Turbines are developing industrial-scale ATS technology. Westinghouse and General Electric are pursuing advancements in utility-scale applications.

Each organization has completed a conceptual design of an ATS, which differs in specifics, but shares many overall features to attain desired efficiencies and restrict emissions.

In general, turbine inlet temperatures are increased; lean, premixed or catalytically enhanced combustors are being developed; less cooling air is being used through improved cooling schemes, upgraded materials, or improved seals; aerodynamic designs are being improved; and better thermal barrier coatings are being developed.

ATS development is bolstered by a consortium of more than 93 universities in 33 states. Coordinated by the South Carolina Energy Research and Development Center, an administrative branch of Clemson University, technological advances are being pursued while fundamental, base knowledge of turbines grows. Central to this knowledge is better understanding of the science of high-temperature, corrosion-resistant materials, combustion, innovative thermodynamic cycles, and how pollutants are formed when fuels are burned and how they can be prevented from forming.

To date, the consortium has selected 51 projects that include: (1) combustion to improve fuel utilization and minimize environmental effects, (2) heat transfer and aerodynamics to upgrade turbine blade life and performance, and (3) materials to extend life and allow higher operating temperatures for more efficient systems.

FETC Contributions

Under the Technology Base Program, FETC scientists have developed a cost-effective and time-saving test combustor for manufacturers to use. This device ensures that a proper match is made between low-emissions combustors and turbines, thereby avoiding turbine damage caused by uncontrolled pressure oscillations. A turbine manufacturer is now using the test combustor, which incorporates cost-saving advantages in its design.

ATS Program Goals


- Efficiencies greater than 60 percent for natural gas, large-scale, utility turbines, and a 15-percent improvement for smaller industrial-scale turbine systems.
- NO_x emissions less than 9 ppm and carbon monoxide and unburned hydrocarbon emissions less than 20 ppm—without post-combustion cleanup.
- Fuel-flexible systems initially designed for natural gas and adaptable for coal-based syngas and biomass fuels.
- Busbar energy costs at 10 percent less than vintage 1992 turbine systems meeting similar environmental standards.
- Reliability, availability, and maintainability equivalent to or better than current state-of-the-art systems.

FETC is working with the United Technologies Research Center (UTRC) to identify and address key R&D issues for humidified combustion turbine cycles. The purpose of this Humid Air Turbine (HAT) research is to identify a combustor configuration that will efficiently burn high-moisture, high-pressure gaseous fuels with low emissions. Using UTRC's experience with aero-derivative engines as a basis, researchers are comparing test data to computer models. Currently, shakedown testing of combustor nozzle designs is occurring; the intent is

to provide scale-up data for subsequent hardware development. The HAT cycle development work supports both gas- and coal-fired advanced cycle systems.

Vision 21

Advanced turbines also figure prominently in the DOE's Office of Fossil Energy Vision 21, a fleet of super-efficient, flexible energy plants for the 21st century. These plants would produce clean, high-efficiency power while simultaneously producing clean fuels, chemicals, or heat as local needs require. Advanced turbines will most certainly be needed to achieve

these realistic and much needed goals for the next century. 

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FETC scientists and engineers, in partnership with university researchers and industrial developers, collaborate to move advanced gas turbine technologies into the marketplace to meet the power needs of the 21st century.

